MACROSCOPIC DYNAMIC BEHAVIOR CHARACTERIZATION OF CATALYTIC CRACKING RISER STATIONARY-NONSTATIONARY ZONES AT SEVERE OPERATING CONDITIONS

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In refining technologies and industry, catalytic cracking is indispensable core process for production of fuels and valuable petrochemicals including gasoline and light olefins, respectively. FCC-DCC processing with worldwide capacity of more than 500 million tons per year are considered the primary contributor of fuel pool. In 2022, Russian Federation invested more than 69 % of refining processes on deep processing technology. Therefore, optimization of catalytic cracking process is our actual research.

Our research about optimization of catalytic cracking process was started with the thermodynamic analysis and consequently the kinetic analysis. Results were published in our previous works [1]. The third step was dedicated to hydrodynamic analysis, which is presented here. In this work, the effect of operating conditions of FCC industrial unit including temperatures of feedstock and regenerated catalyst and CTO (cat. to oil ration) on hydrodynamic behavior of the process in transient and non-transient zones was analyzed. Results were compared with previous publication of our team [2] for further investigation. Table 1 shows the governing equations in this hydrodynamic modeling programming using E–E transient, 3-D, 2-phases fluid-solid computational modeling with consideration of heat transfer and kinetics of reactive flow. In governed equations, the subscripts g and s indicates gas and solid phases. The ε, ρ, U, μ, g, p, G are volume fraction, density and velocity of phases, viscosity, gravity acceleration, pressure and elasticity modulus. M is interface momentum transfer based on Gidaspow drag model. H, T and λ are static enthalpy, temperature and thermal conductivity. γ states for interphase heat transfer coefficient based on Nusselt number. In this work five-lump kinetic reactions modeling was utilized including gasoil, gasoline, light gases and coke.

Two cases of operating conditions studied in this work compared with industrial condition consists of feedstock temperature, catalyst temperature and CTO of 408.85 K, 649.85 K and 8, respectively. Case I: feedstock T., catalyst T. and CTO – 748.9 K, 913 K, 12, respectively. Case II: feedstock T., catalyst T. and CTO – 788 K, 1013 K, 6, respectively.

Table 1. Governing equations of gas and solid phases

Continuity equations of gas and solid particles:

$$\frac{\partial}{\partial t}(\varepsilon_g\rho_g) + \nabla\bullet(\varepsilon_g\rho_g U_g) = 0 \quad (1)$$

$$\frac{\partial}{\partial t}(\varepsilon_s\rho_s) + \nabla\bullet(\varepsilon_s\rho_s U_s) = 0 \quad (2)$$

Conservation of momentum of gas and solid phases:

$$\frac{\partial}{\partial t}(\varepsilon_g\rho_g U_g) + \nabla\bullet(\varepsilon_g\rho_g U_g U_g) = \nabla\bullet[\varepsilon_g\mu_g(\nabla U_g + (\nabla U_g)^T)] + \varepsilon_g\rho_g g - \varepsilon_g\nabla p + M \quad (3)$$

$$\frac{\partial}{\partial t}(\varepsilon_s\rho_s U_s) + \nabla\bullet(\varepsilon_s\rho_s U_s U_s) = \nabla\bullet[\varepsilon_s\mu_s(\nabla U_s + (\nabla U_s)^T)] + \varepsilon_s\rho_s g - \varepsilon_s G\nabla\varepsilon_s - M \quad (4)$$

Heat transfer equations:

$$\frac{\partial}{\partial t}(\varepsilon_g\rho_g H_g) + \nabla\bullet(\varepsilon_g\rho_g U_g H_g) = \nabla\bullet(\varepsilon_g\lambda_g\nabla T_g) + \gamma(T_s - T_g) + \varepsilon_g\rho_g\sum_r \Delta H_r\frac{\partial C_r}{\partial t} \quad (6)$$

$$\frac{\partial}{\partial t}(\varepsilon_s\rho_s H_s) + \nabla\bullet(\varepsilon_s\rho_s U_s H_s) = \nabla\bullet(\varepsilon_s\lambda_s\nabla T_s) + \gamma(T_g - T_s) \quad (7)$$

Table 2. Results of dynamic behavior modeling for components mass fraction

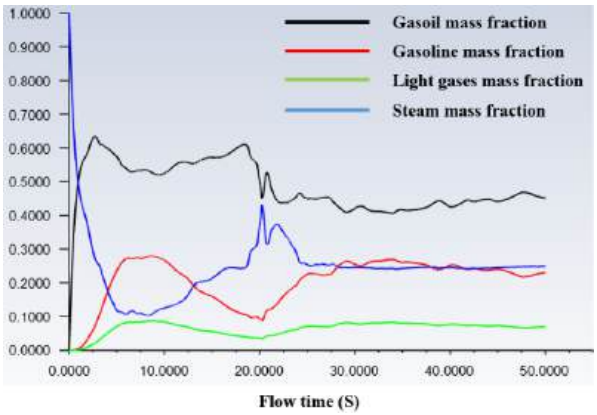
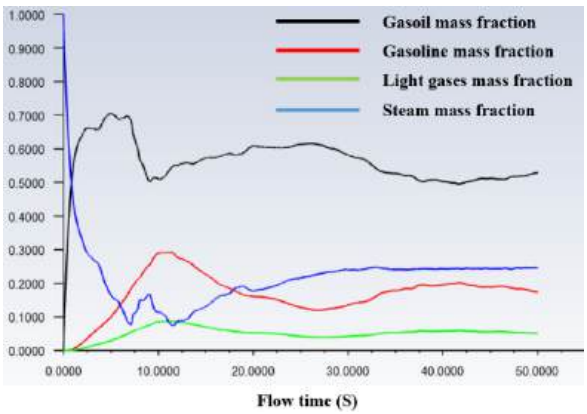
Case I	Case II
	

Table 2 represents the results for components mass fraction and catalyst mass fraction versus time. Case I has more severe operating temperatures and CTO compared with industrial case, while case II has more severe temperatures and less CTO regarding to industrial condition. It was observed from the figures that intransient state switches to transient state at 22–25 s, and 32–35 s for cases I and II, respectively, while the industrial operating case reported in previous work [5] showed 35–40 s for reaching to transient state.

It can be concluded that operating conditions has considerable effect on state of flow regime. However, the interaction of parameters can be further investigated in our future perspective.

References

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PROCESSING POLYMER WASTE INTO VALUABLE RAW MATERIALS

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In the last few decades the use of polymer materials has noticeably increased due to their relatively low price and a number of unique qualities: resistance to many acids and alkalis; resistance to organic solvents (alcohols and ketones); elasticity, which allows shaping a product; high strength which guarantees long usage.

In addition to this, polymer materials do not corrode, have low thermal conductivity and light weight of a final product in comparison with the product made of wood, glass or metal; besides, polymers can be easily recycled and used again in production, which allows reducing the cost of raw materials purchasing.